Mercury Sources, Transport, and Fate in the Atmosphere

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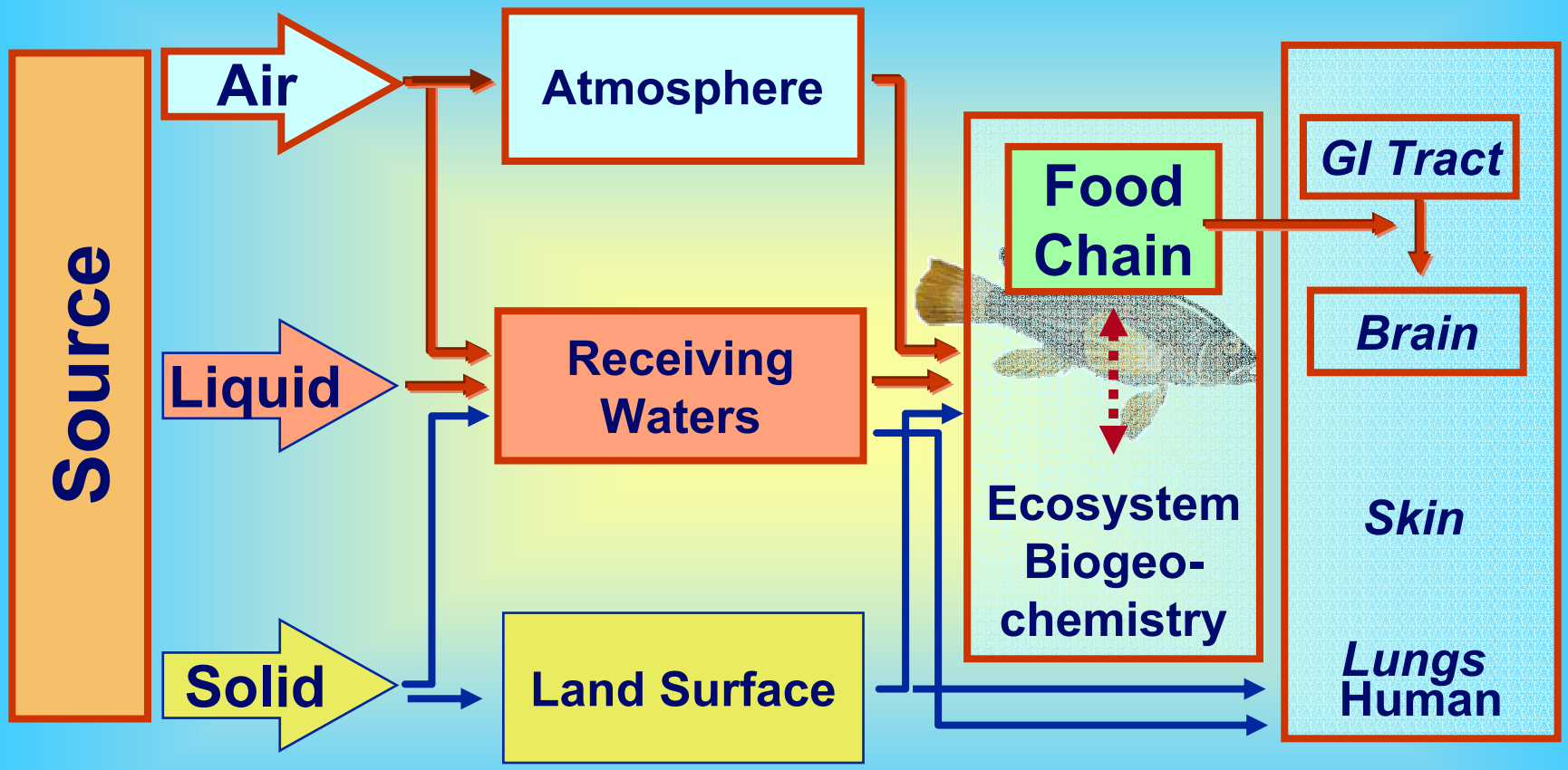
Potential Toxics Exposure in Humans (major mercury pathways in red)



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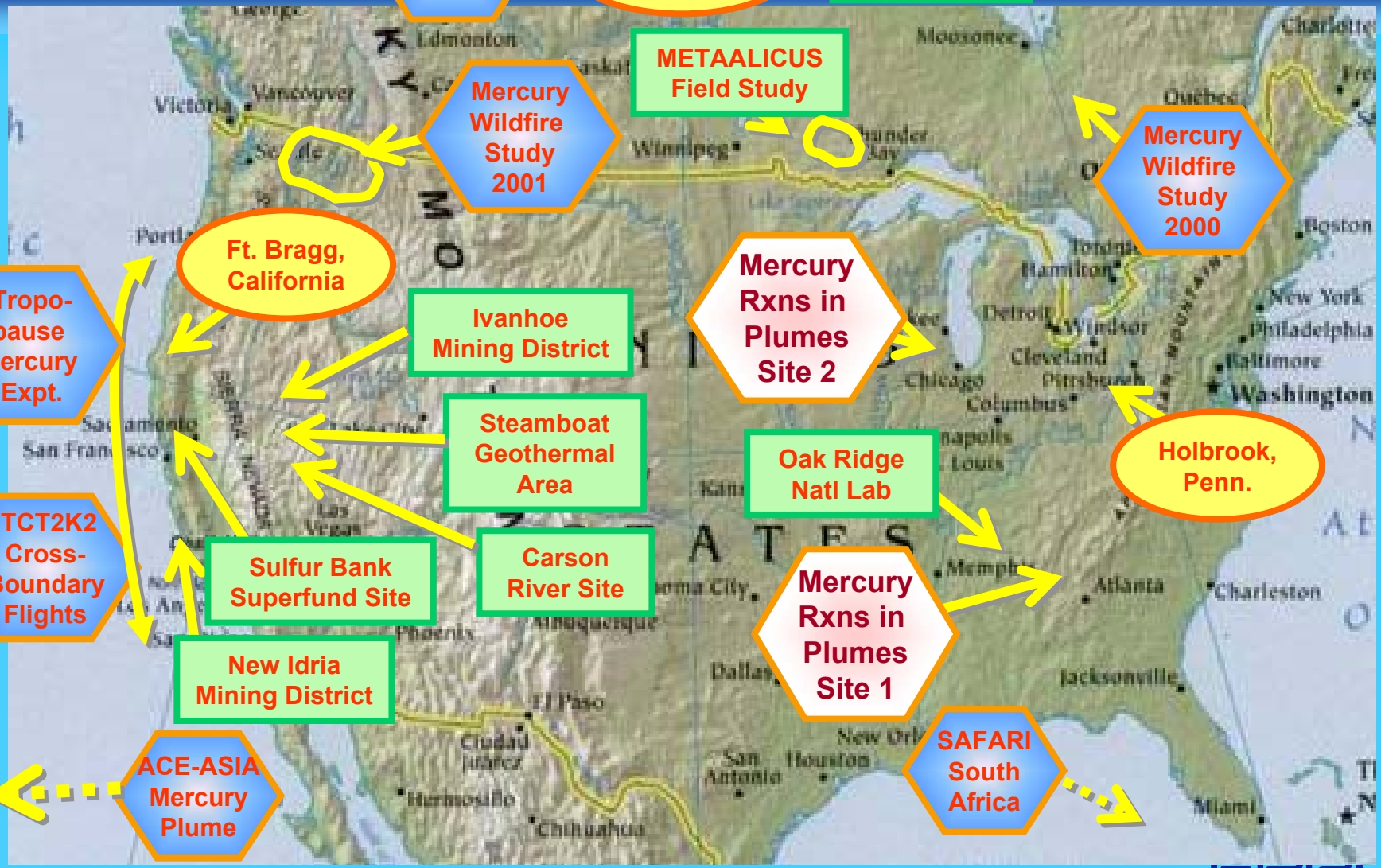
Chemical forms of Mercury

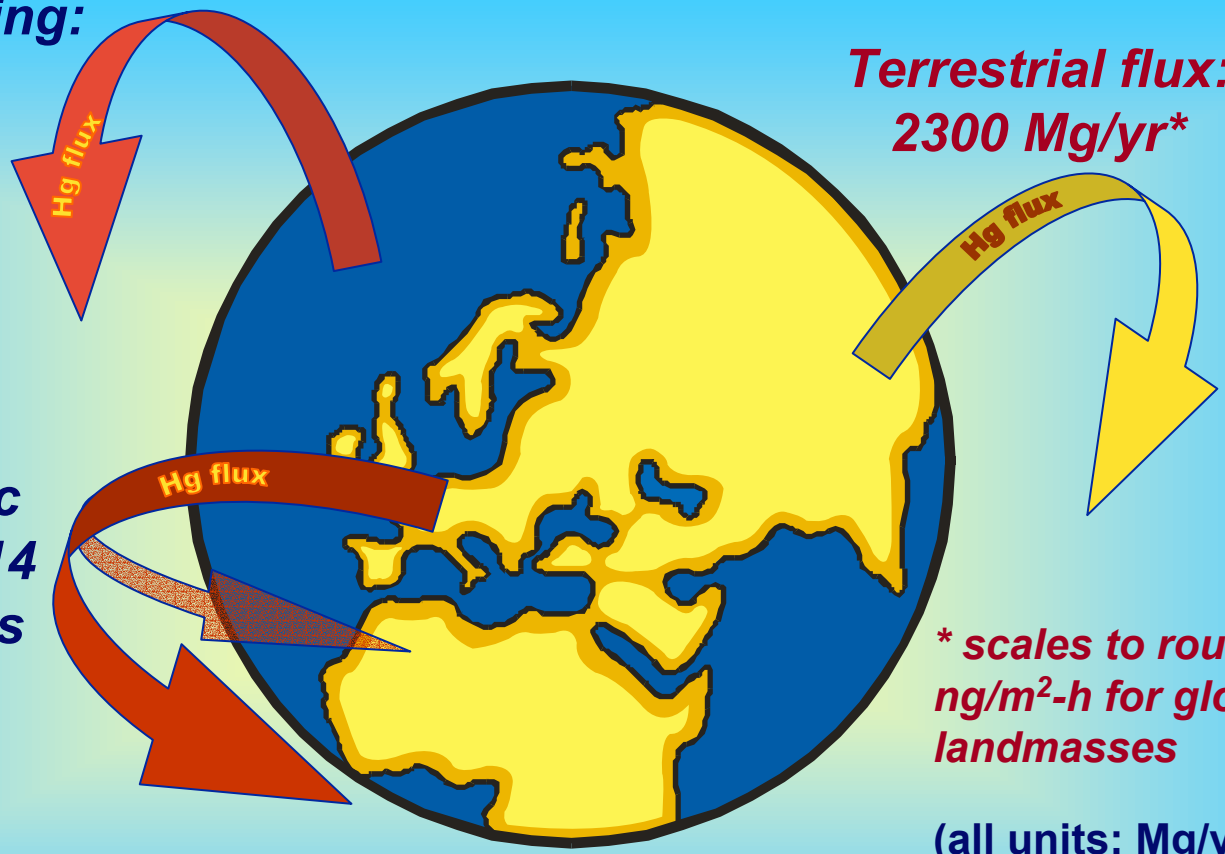
- Inorganic mercury
  - Elemental: Hg(0), the silvery liquid metal
  - Divalent: Hg(II), often combined with chlorine
- Organic mercury
  - Monomethylmercury: MeHg, usually with chlorine; may be formed in aquatic systems
  - Dimethylmercury: highly toxic; reactive; occurrences: landfills; marine mammals?
  - Other forms

Mercury Field Study Sites (2000-2003)



Mercury Balance to the Global Atmosphere

Ocean Outgassing: 2000 Mg/yr



*Terrestrial flux: 2300 Mg/yr**

Anthropogenic emissions: 2214 Mg/yr (1/2 goes to local deposition)

** scales to roughly 1.8 ng/m^2-h for global landmasses*

(all units: Mg/yr = 10^6g/yr = metric tons/yr)

Global atmospheric lifetime (Hg^0): 1-1.5 yr

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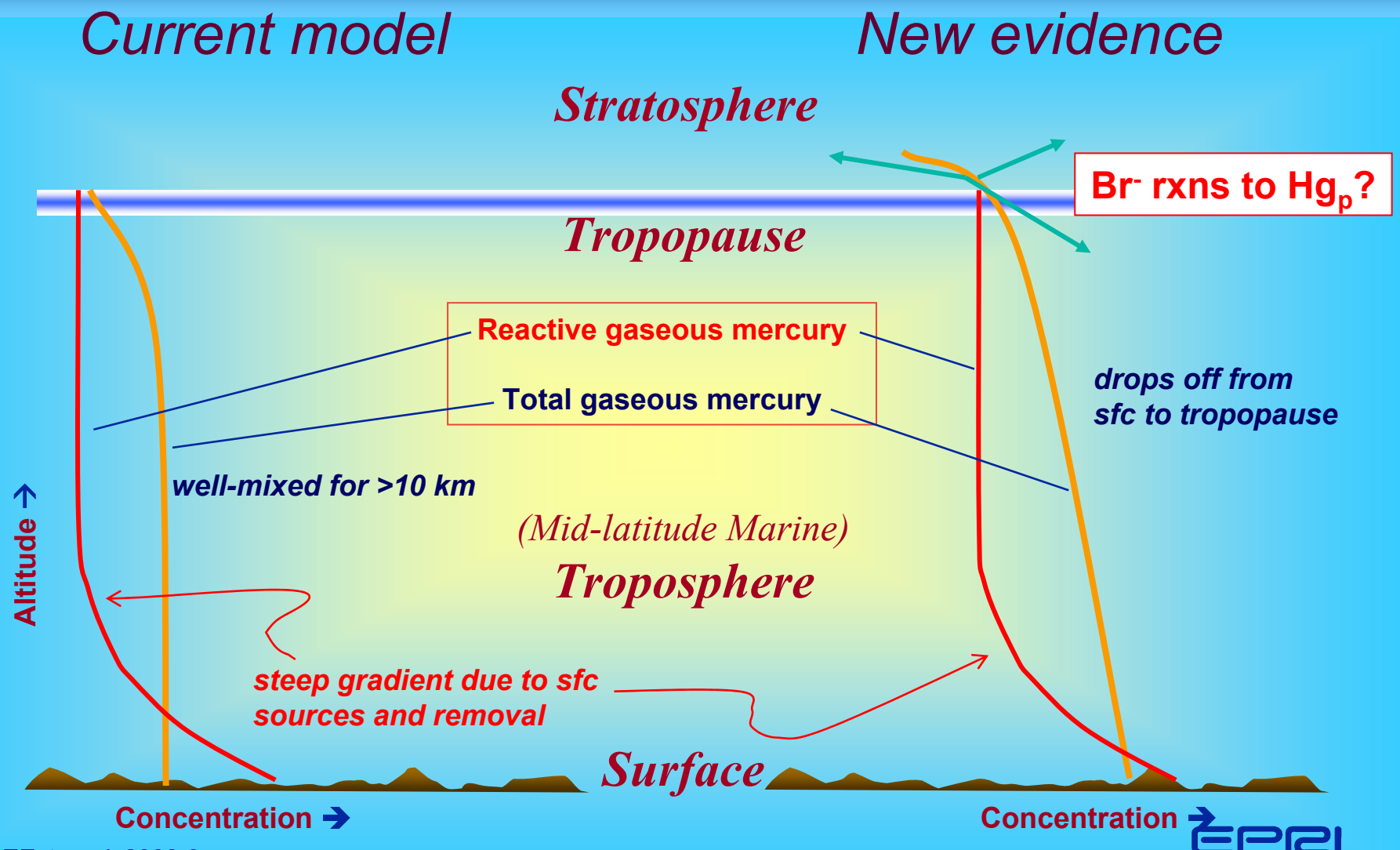
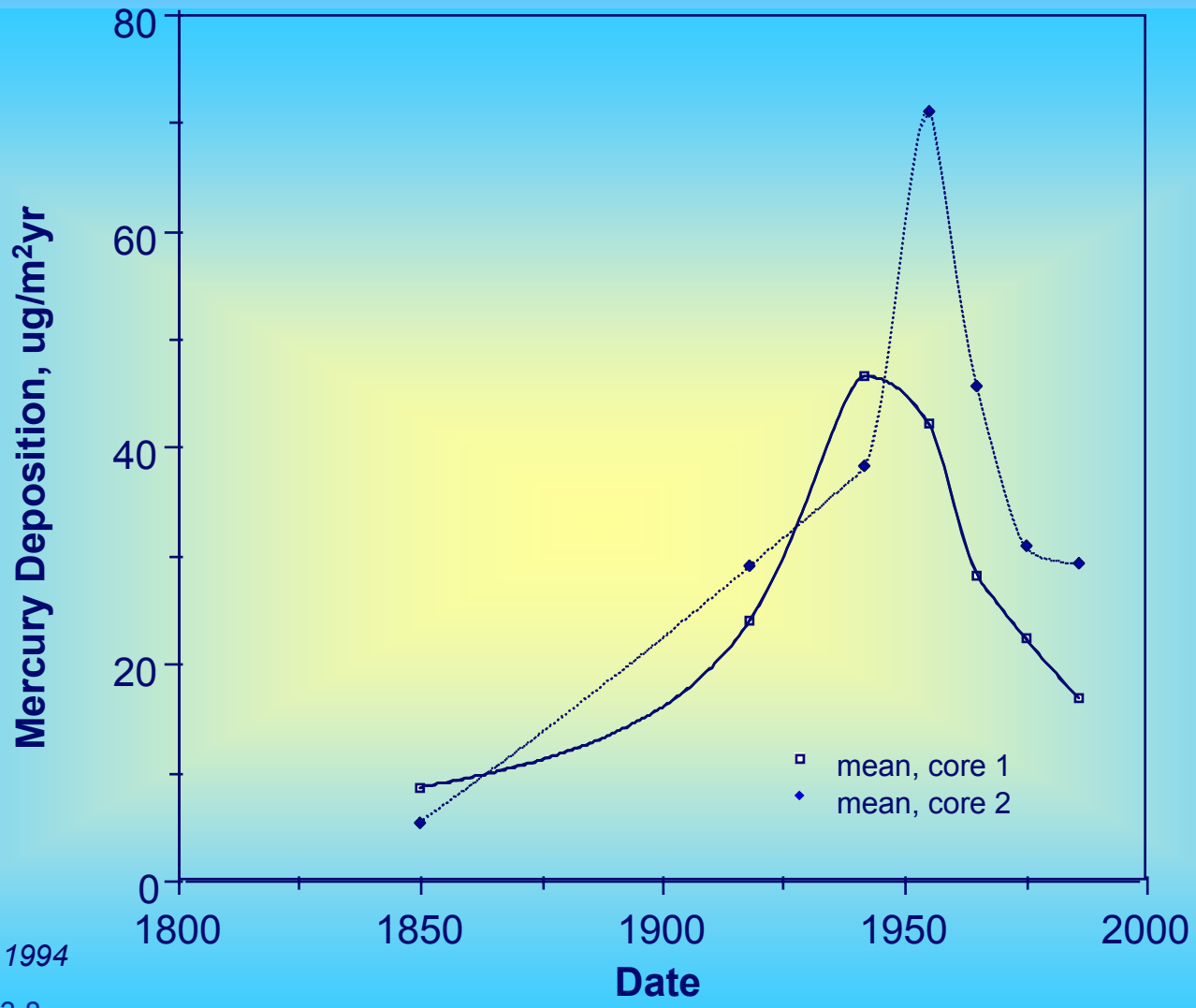
New Evidence on Global Lifetime



SWEDEN: A "natural" mercury experiment

- 20 years monitoring of mercury deposition
- Deposition from atmosphere: 50% drop in early 90s: due to changes in Eastern Europe
- Fish mercury: about 20% average drop
- Complication: similar drop in SO_4^{-2}: may have led to lower methylation rates

Trends in Mercury Deposition - 2 Northern Wisconsin Bogs



From: Benoit et al. 1994

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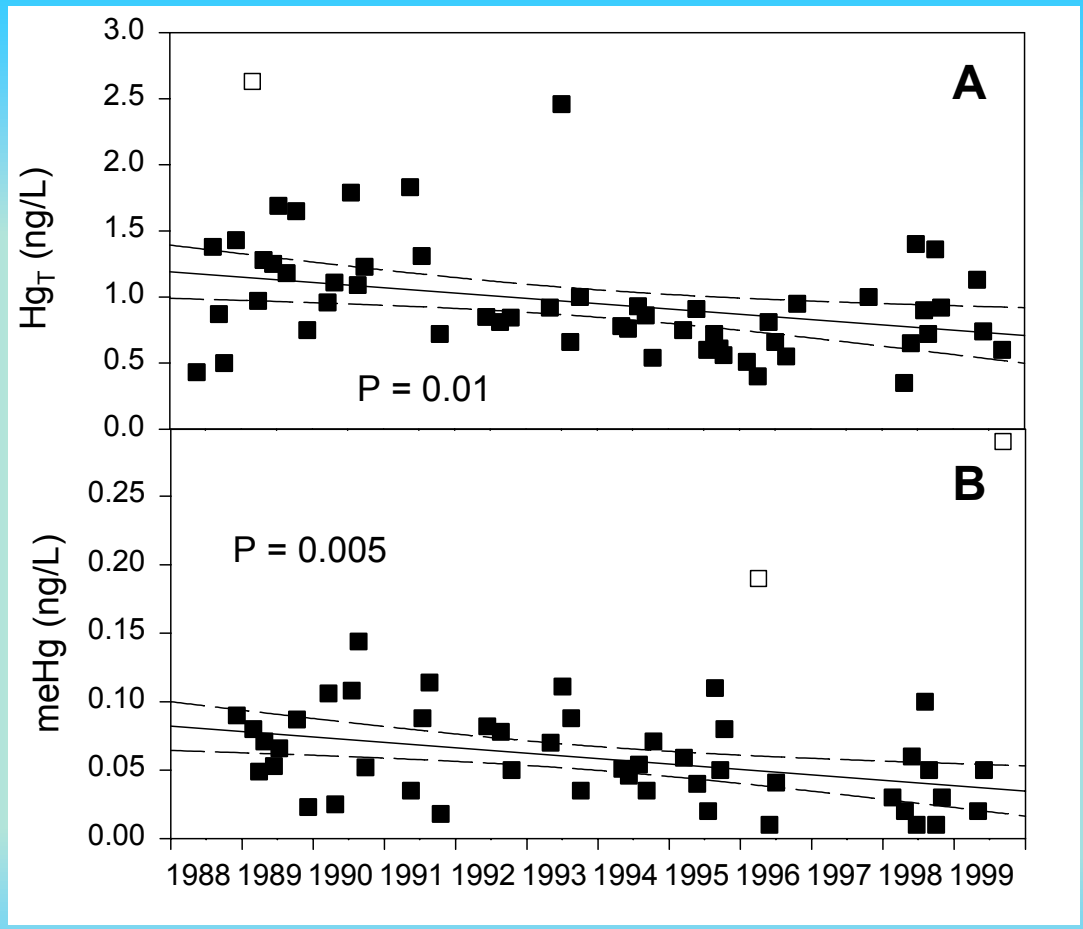
MERCURY TRENDS OVER TIME
Little Rock Lake, WI (reference basin)



Watras et al., 2000; ES&T

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Of the total mercury emitted into the atmosphere from a single source …

… 20% deposits nearby

Deposition

… & 80% disperses into the global atmosphere

Dispersion

97% or so goes into bottom sediments

… & a small fraction get methylated, some going into fish

But in some fish, the mercury builds up to higher levels

Human Exposure

Some mercury concentrations

1000 in a billion ***= 1 ppm (part per million)***

- **Mercury (mostly methylmercury) in fish (Dellinger et al.)**

100 in a billion

- **Elemental mercury, from fillings, in saliva (Liang & Brooks)**
- **Mercury in coal (Chu & Porcella)**
- **Mercury in soil (Gustin et al.)**
- **Methylmercury in hair, controlled dose experiment (Gearhart et al.)**

10 in a billion – Methylmercury in blood (Wheatley & Paradis)

1 in a billion ***= 1 tennis ball in the Rose Bowl***

100 in a trillion ***= 1 tennis ball in 10 Rose Bowls***

10 in a trillion – Mercury in air over mine tailings (Gustin et al.)

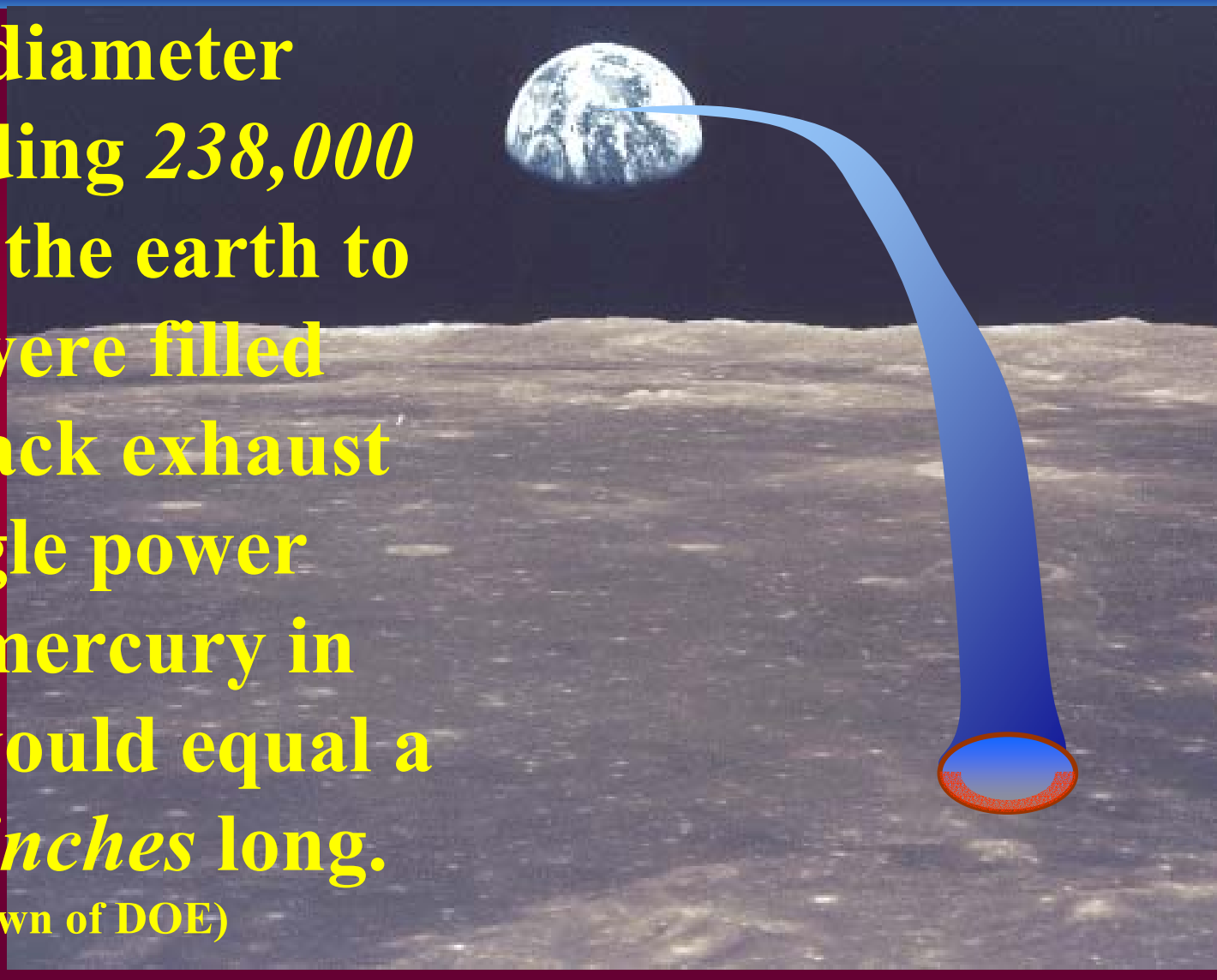
1 in a trillion ***(1/1000th of a billion) = 1 ng/liter***

Mercury in sea or lake water (Fitzgerald et al.) (Driscoll et al.)
Mercury in coastal atmosphere (Iverfeldt et al.)

Mercury in Power Plant Stacks

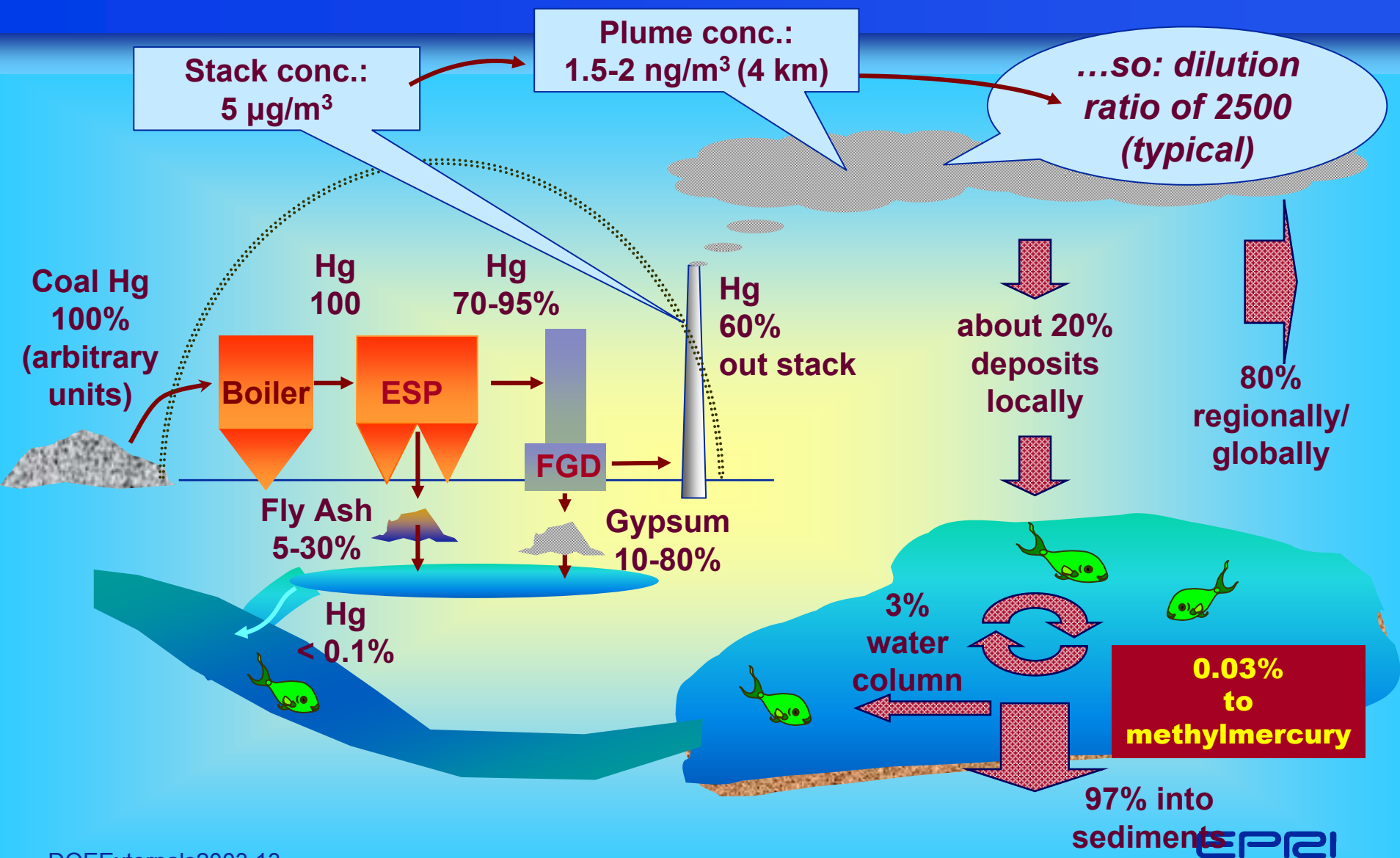
If a 1-foot diameter pipe extending *238,000 miles* from the earth to the moon were filled with the stack exhaust from a single power plant, the mercury in that pipe would equal a section *18 inches* long.

(thanks to Tom Brown of DOE)



Fate of Power Plant Mercury in the Environment

– from METAALICUS and Aircraft Measurements



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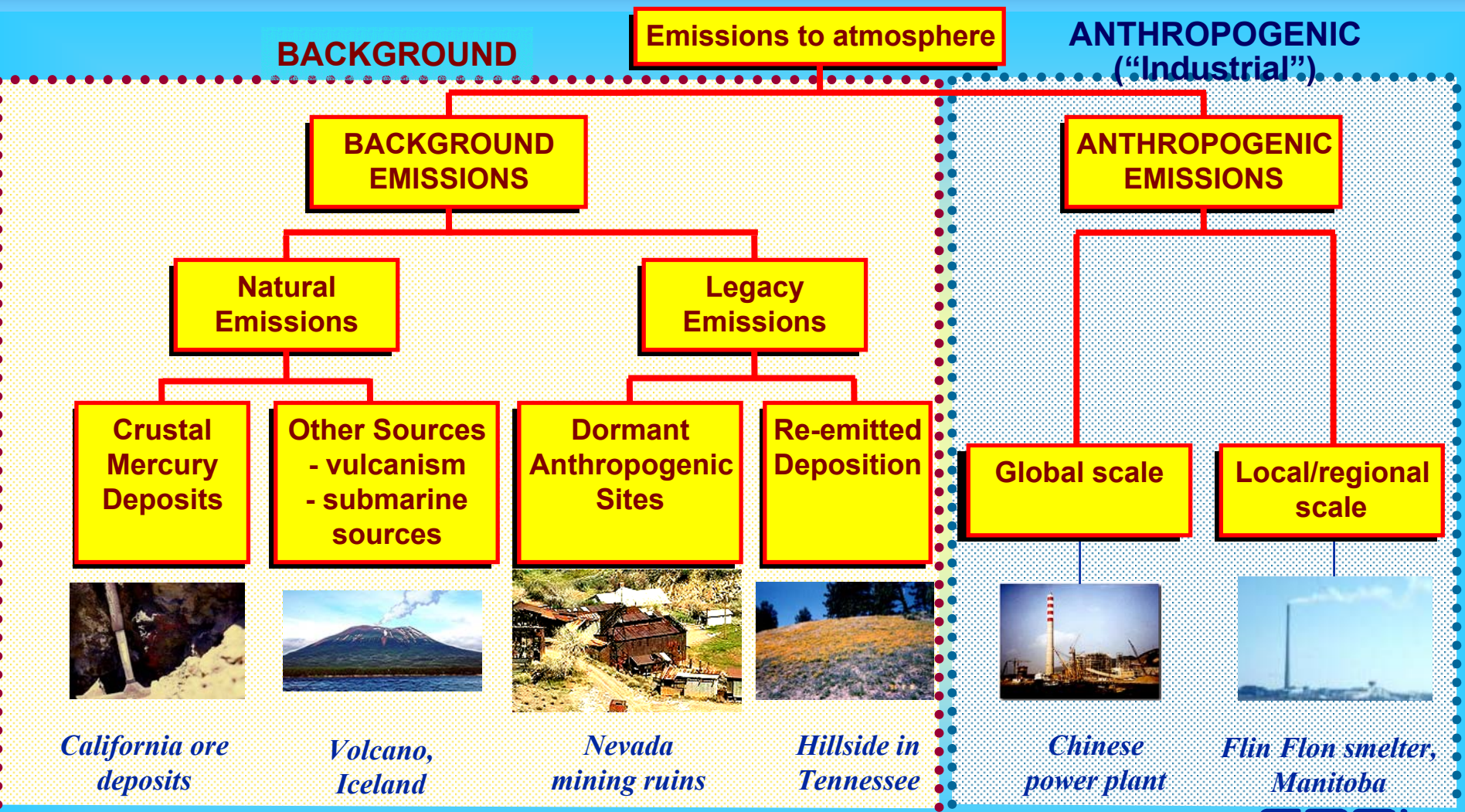
Mercury source hierarchy



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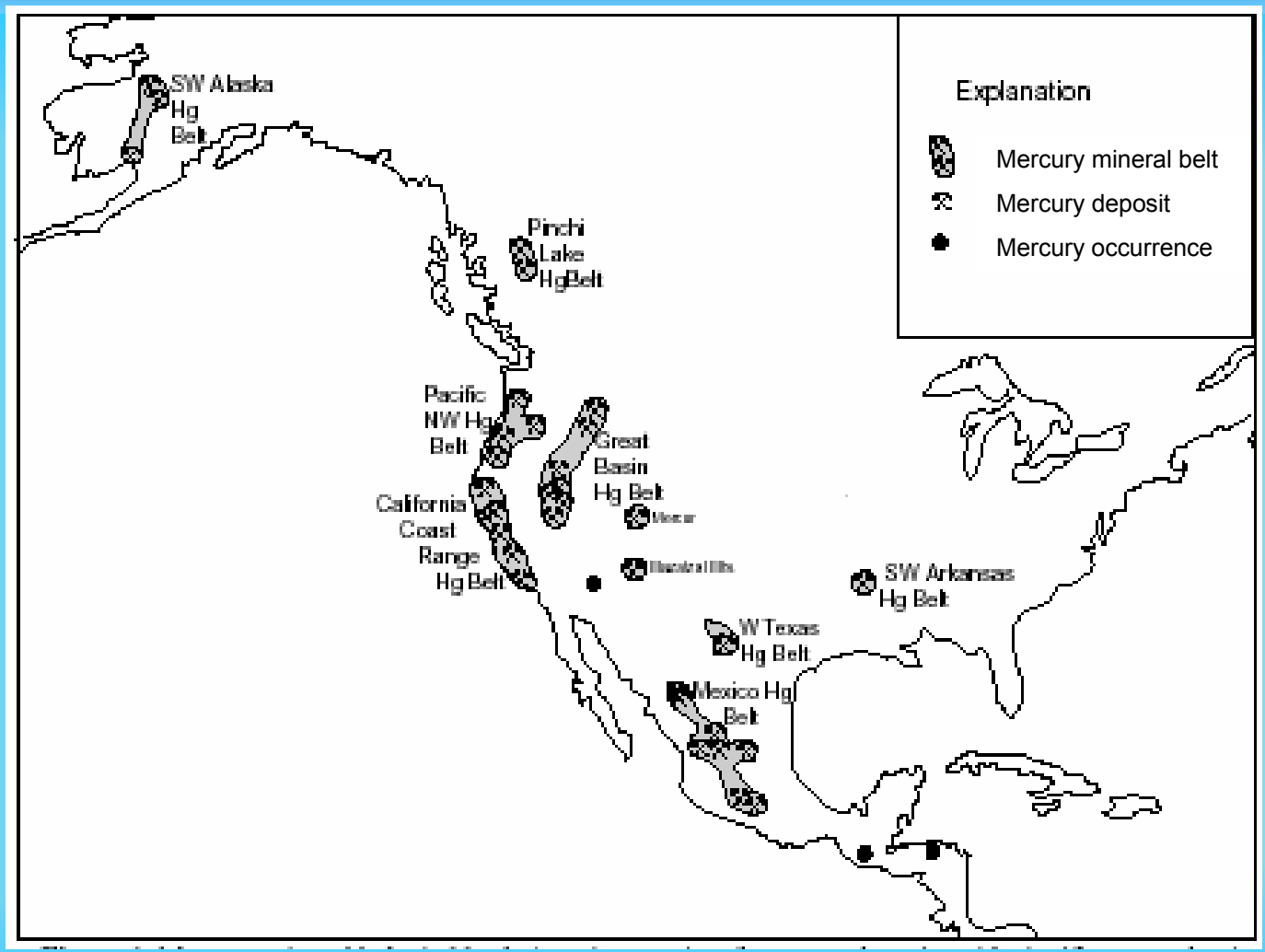
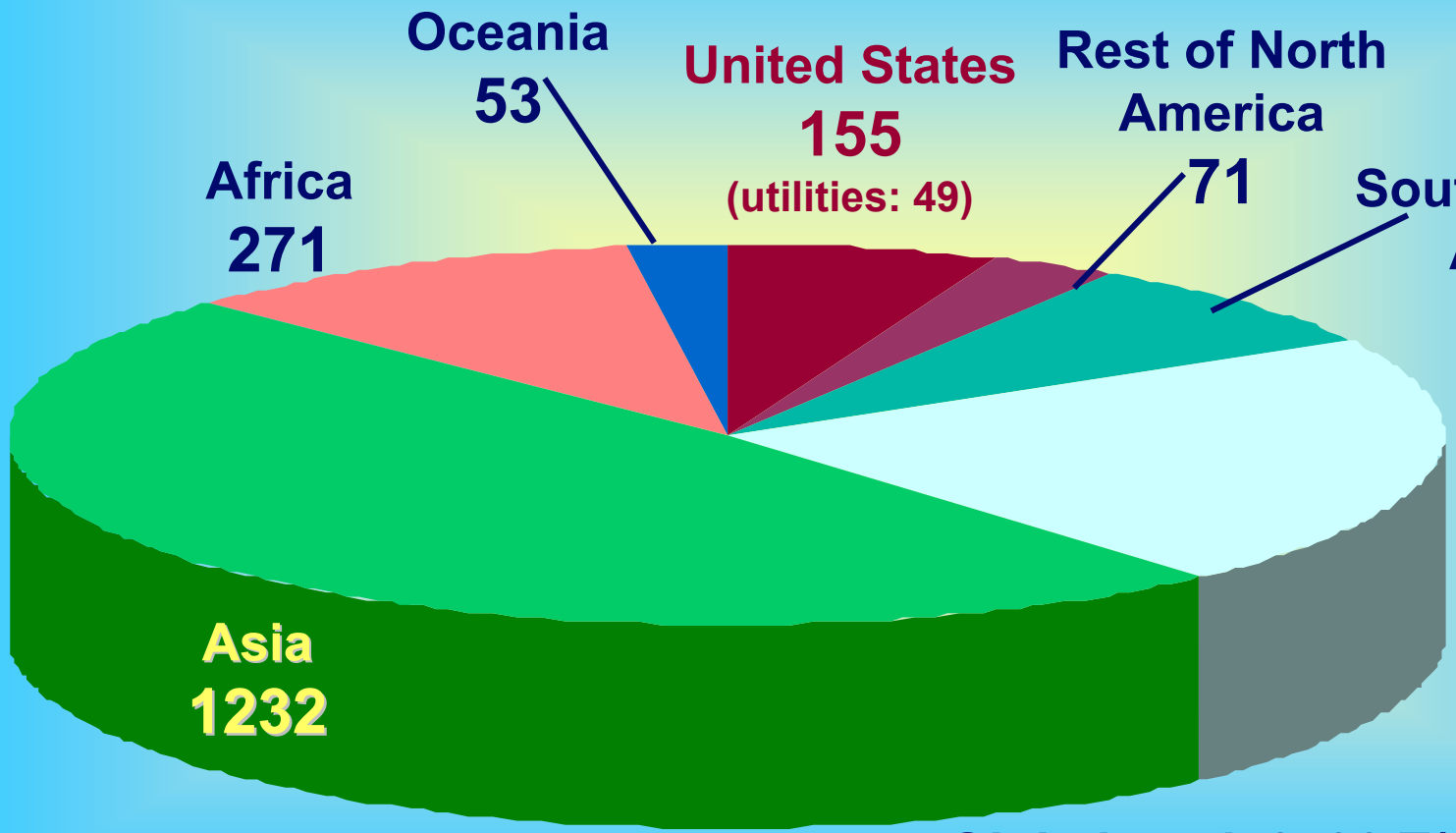
Mercuriferous belts of North America



Nevada STorMs Project Site

Contributions to Global Anthropogenic Emissions of Mercury, by Continent (tons per year)



Global total: 2536 T/y

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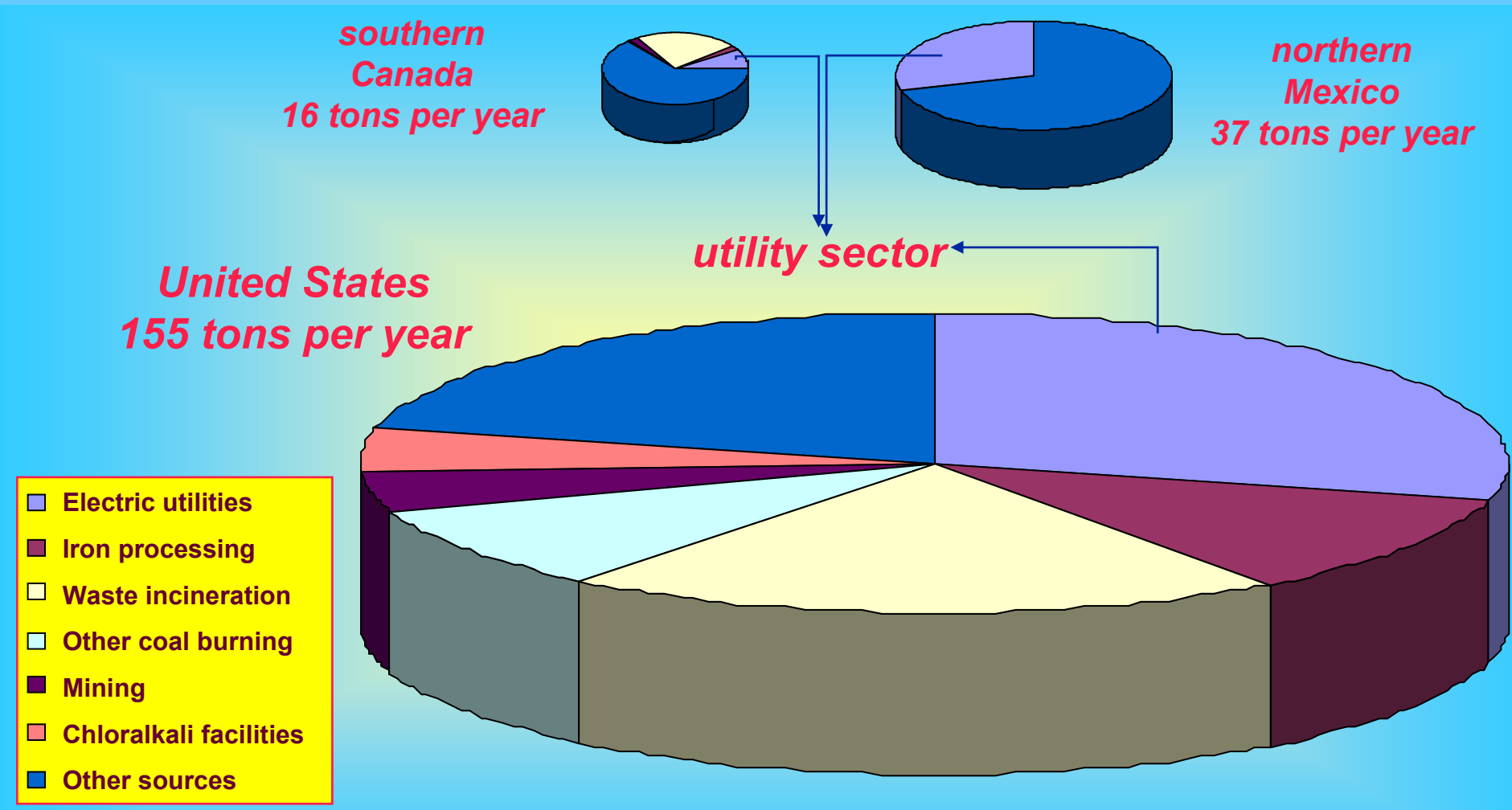
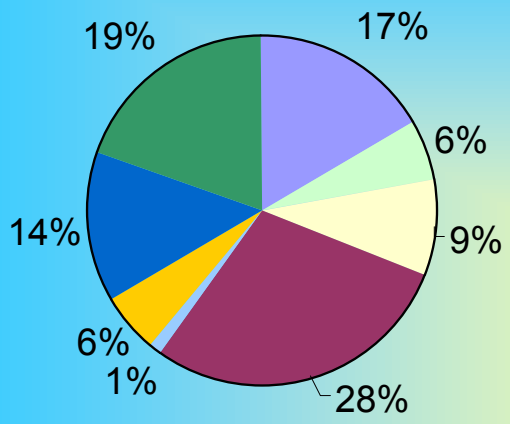
Mercury Source Apportionment, North America

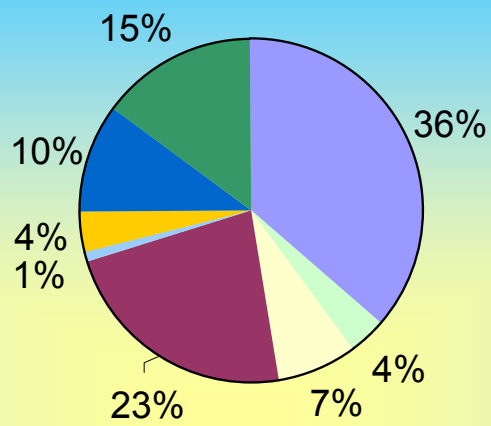


Where Does U.S. Mercury Originate? Global Contributions to U.S. Hg Deposition

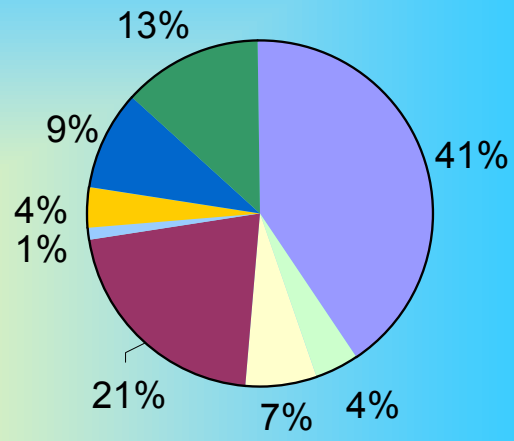
Everglades, Florida



Devil's Lake, Wisconsin



Huntington Wildlife Refuge, New York



Industrial Emissions

- N America
- S&C America
- Europe
- Asia
- Oceania
- Africa

Background Emissions

- Ocean
- Terrestrial

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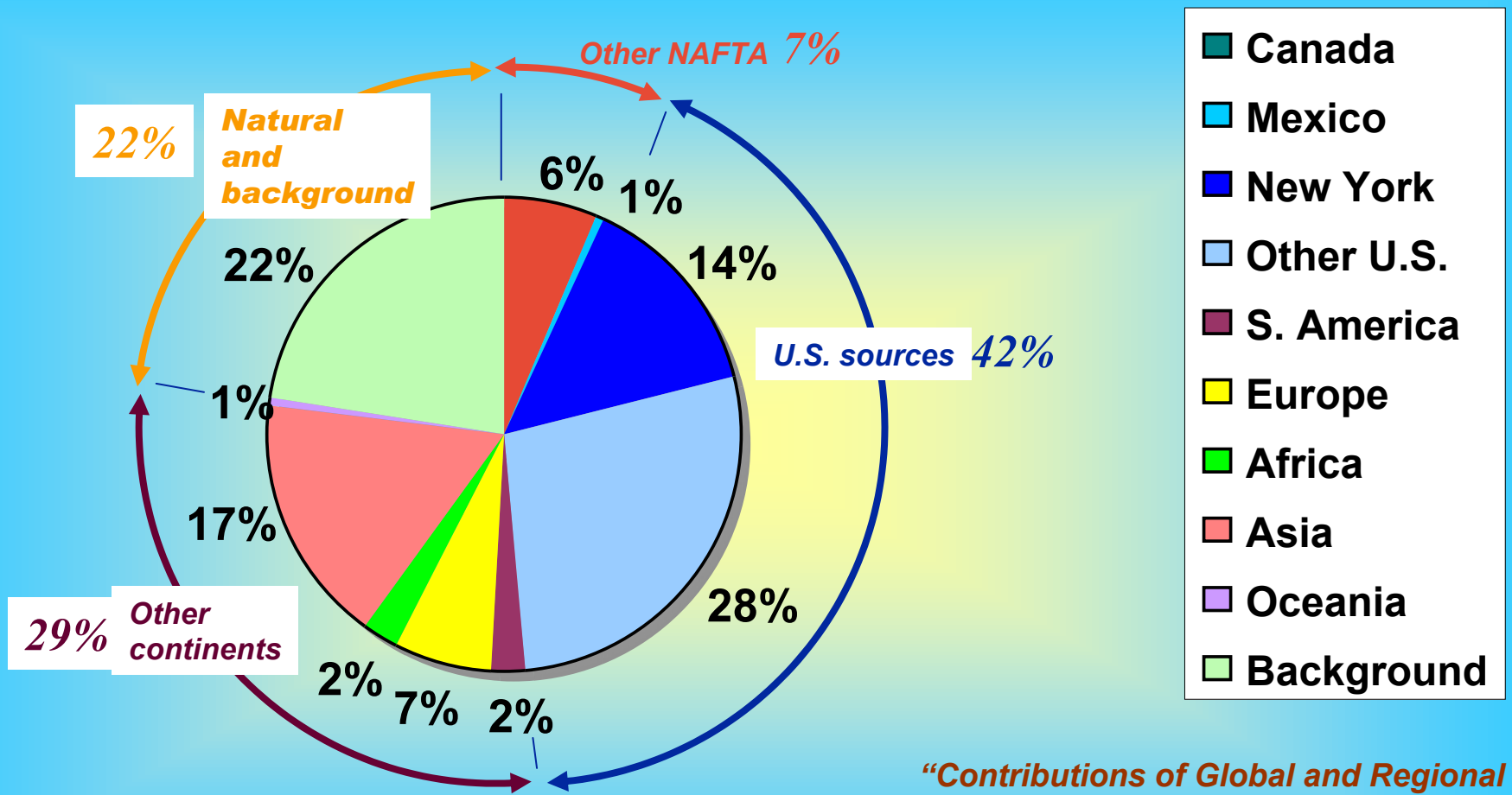
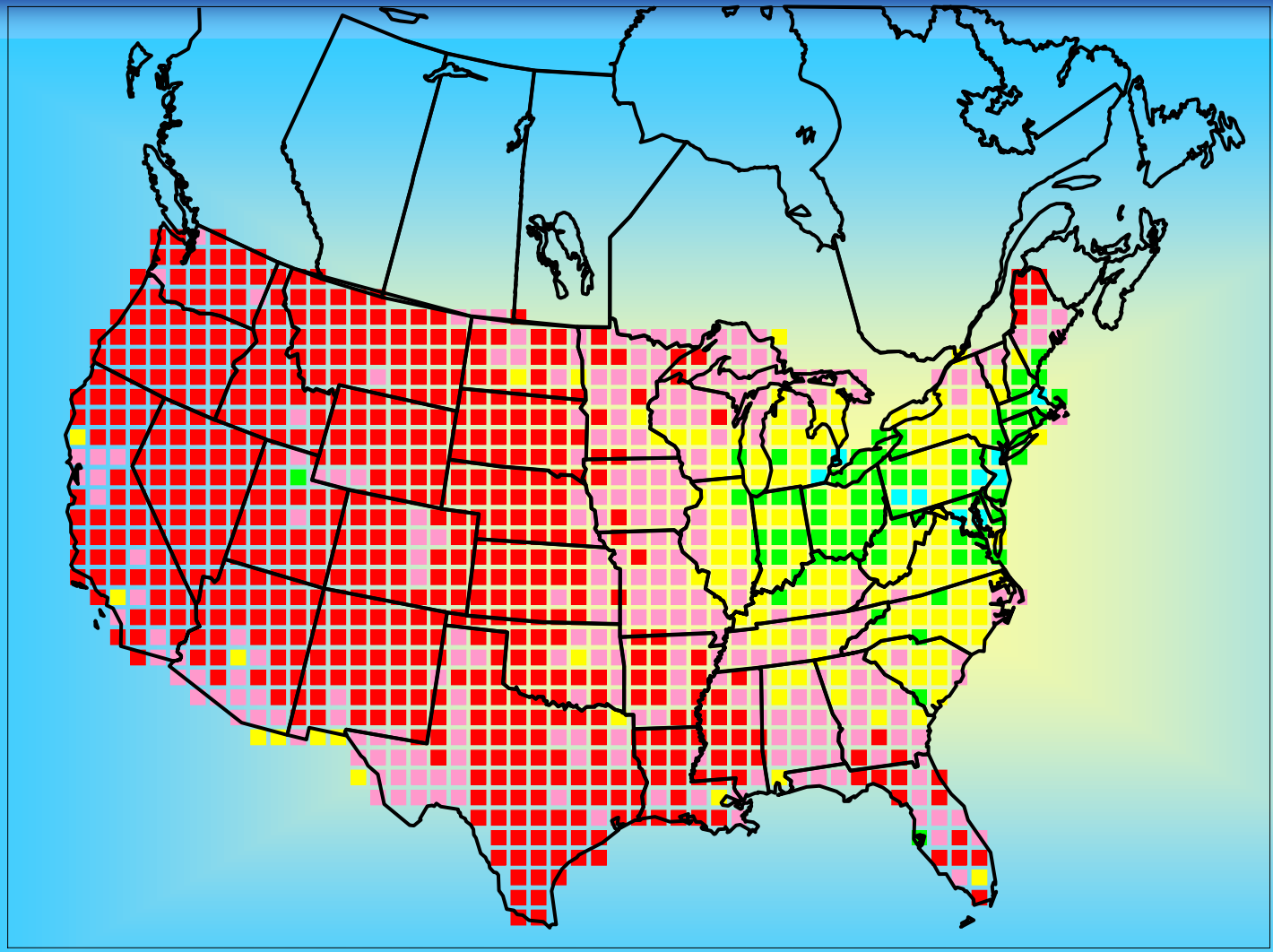
Where Does U.S. Mercury originate? New York State study

EPRI TEAM Model – Case study: Adirondacks region, New York



"Contributions of Global and Regional Sources to Mercury Deposition in New York State," NYSERDA 2002

How much do other parts of the world contribute to U.S. mercury deposition?



Percent of U.S. mercury deposition originating in other countries, or from background and natural emissions

- 0 to 20%
- 20 to 40%
- 40 to 60%
- 60 to 80%
- 80 to 100%

EPRI TEAM regional model, global chemical model

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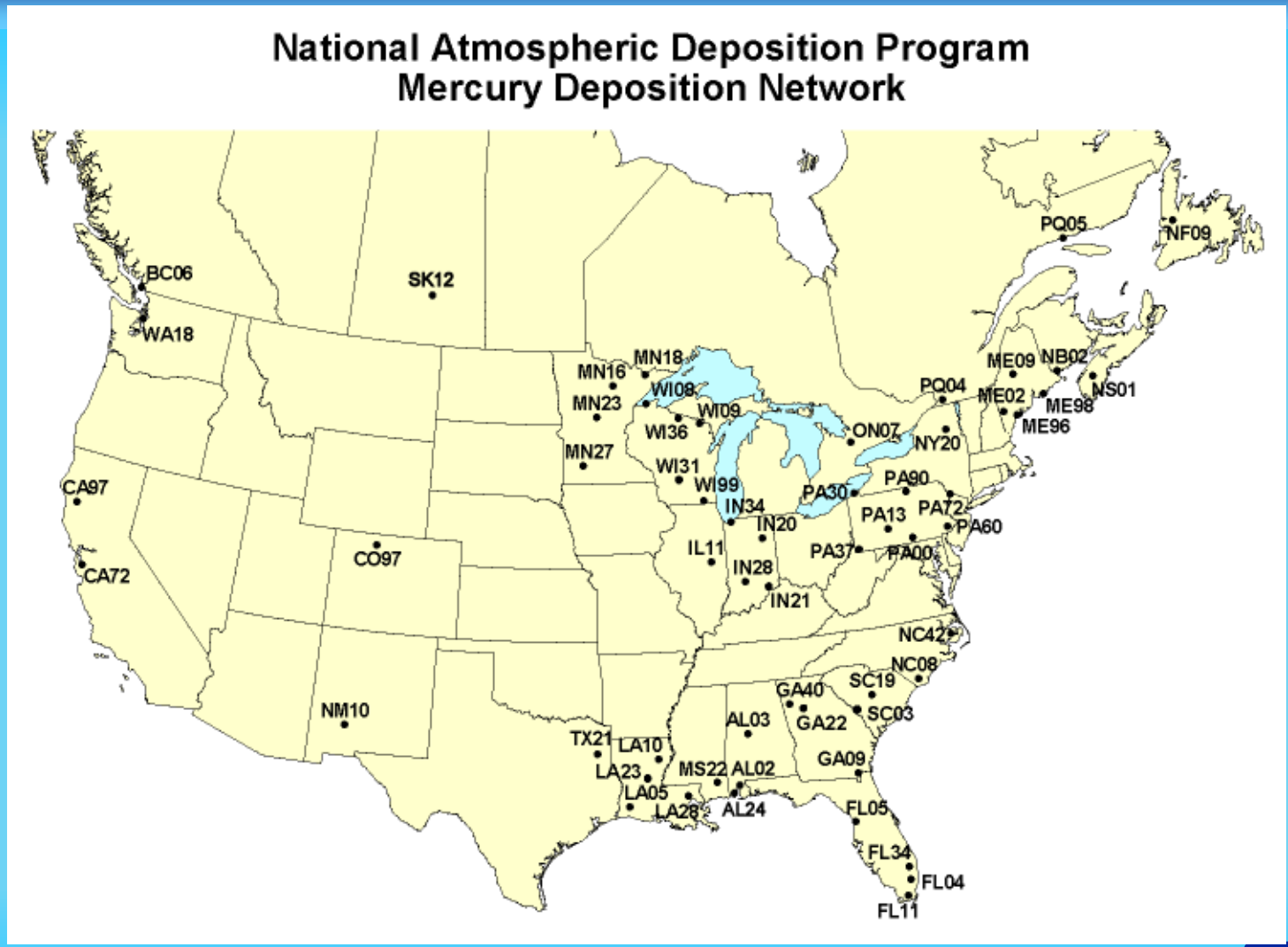
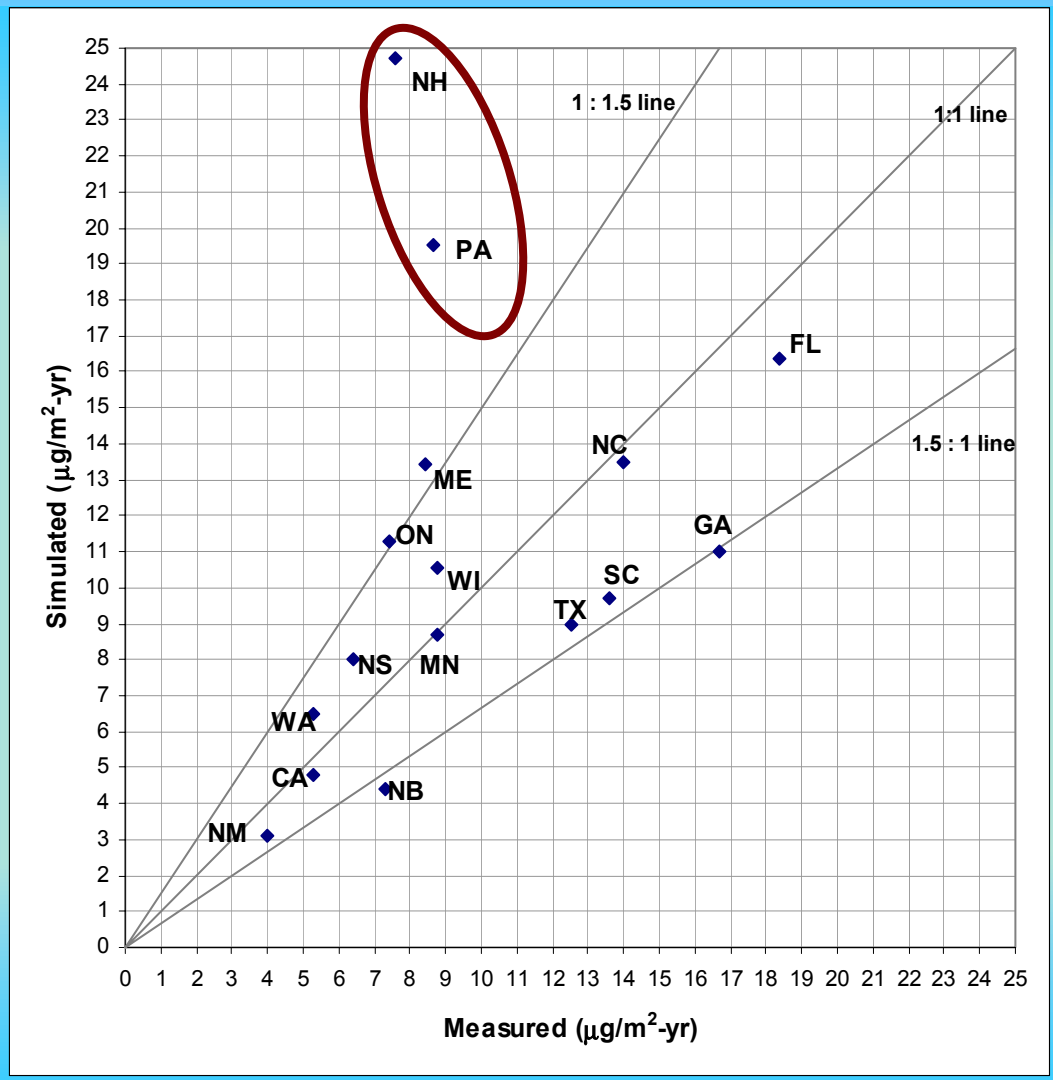
Mercury Wet Deposition Network, 1998 Stations

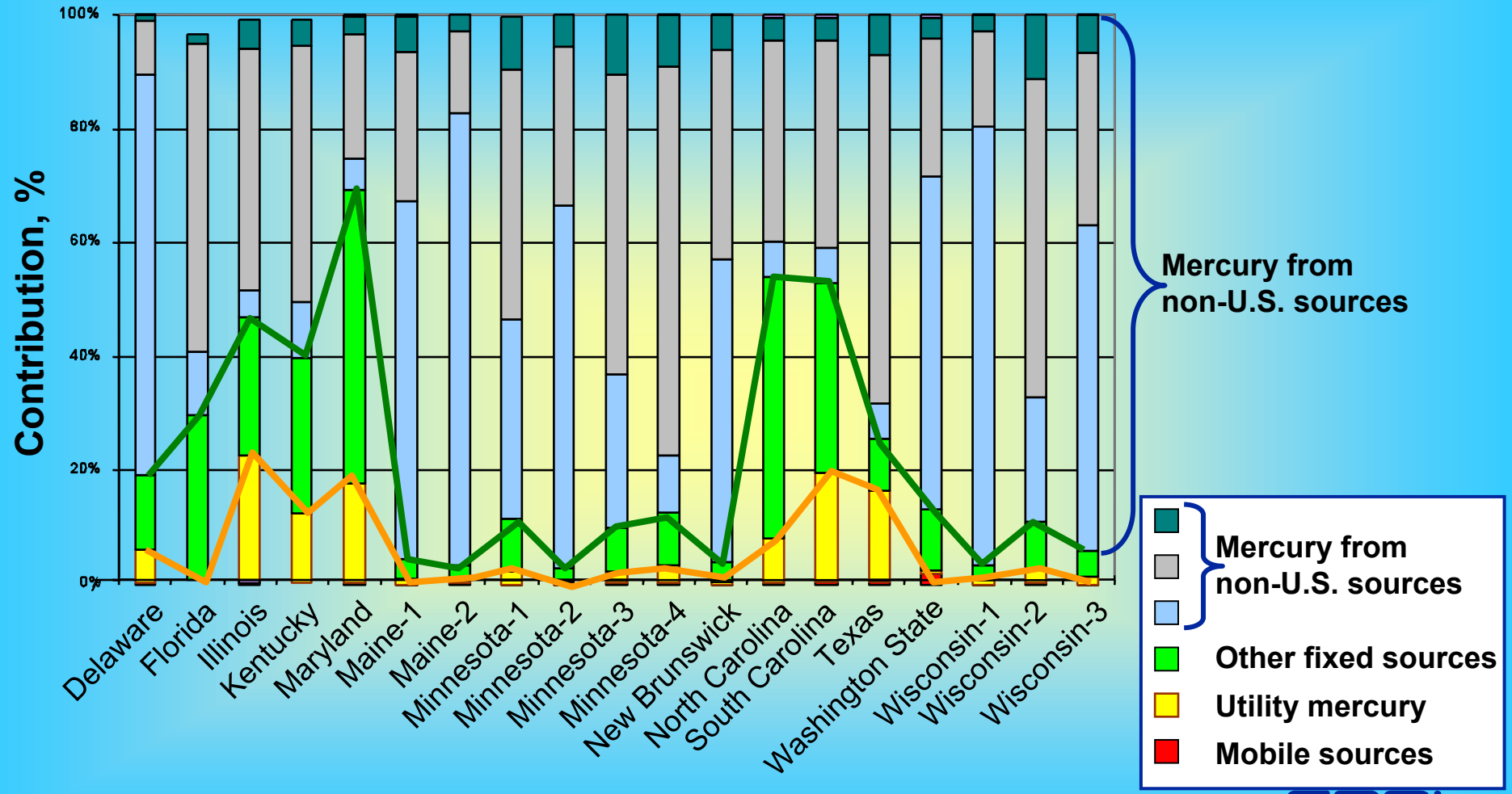


Performance Evaluation, EPRI TEAM Model (Coarse Grid) vs. Observation, Mercury Wet Deposition



How much does utility mercury contribute to the mercury that comes down in the U.S.?

EPA REMSAD model: contributors to mercury at MDN stations



Direct measurements in power plant plumes

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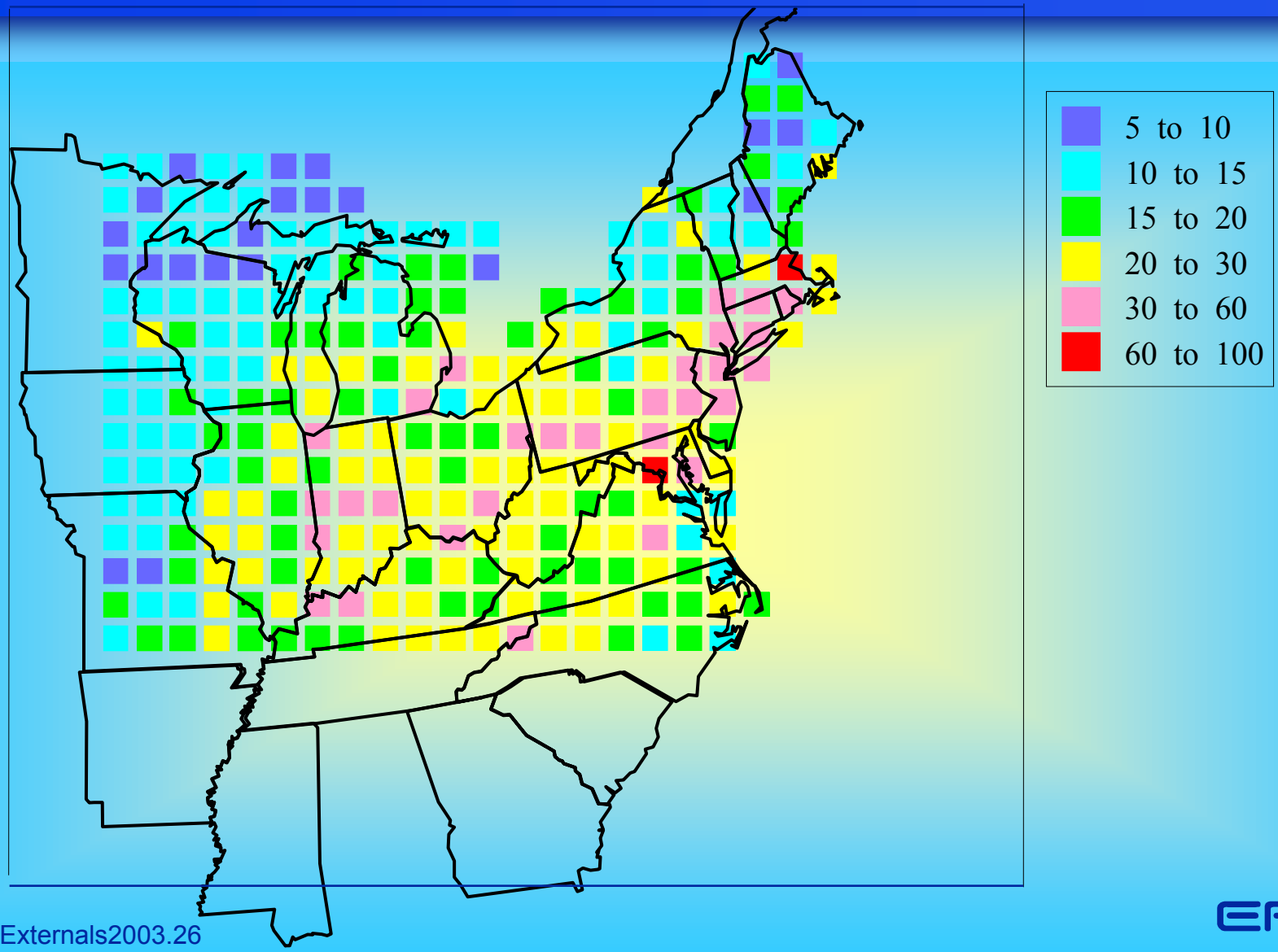
Total Deposition of Total Mercury, Coarse Grid (μg/m^2-yr)



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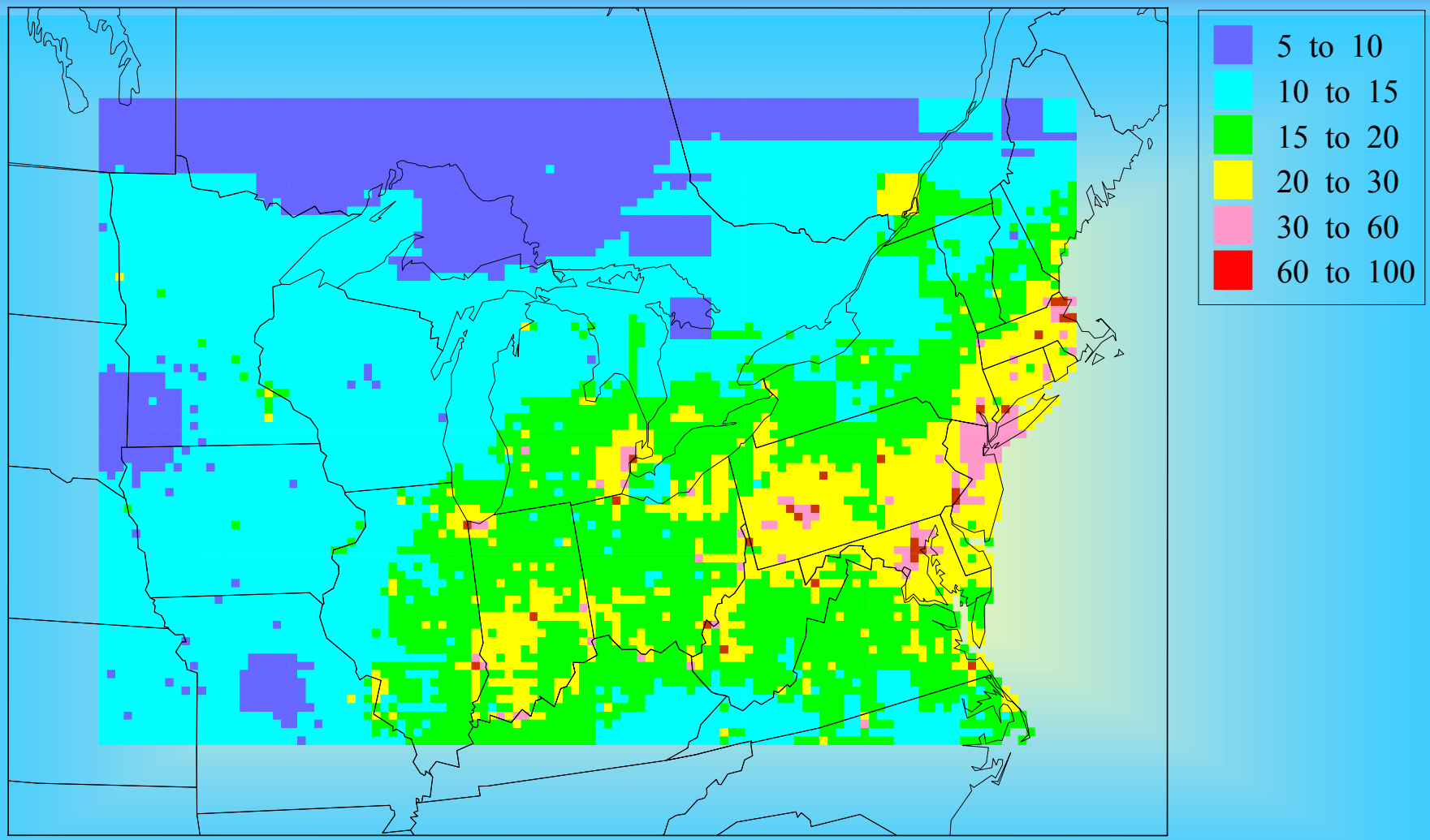
Total Deposition of Total Mercury, Fine Grid (μg/m²-yr)



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Modeling the Consequences of Mercury Emissions Controls

	Total Coal Plant Mercury EMISSIONS, tons/yr	% Difference in mercury EMISSIONS from Base Case	Total Mercury DEPOSITION in the U.S. [wet + dry, Hg(tot)], tons/yr, ALL MERCURY SOURCES	% Difference in all U.S. mercury DEPOSITION from Base Case
CURRENT CONDITIONS (Base Case)	45.6		179	
Scenario 1 ***(No subcategorization)*** MOST SEVERE CONTROLS	24.3	- 47%	173	-3.4%
Scenario 2 ***(Subcategorization by coal rank: bituminous vs. subbituminous vs. lignite)***	31.7	- 30%	174	- 2.7%

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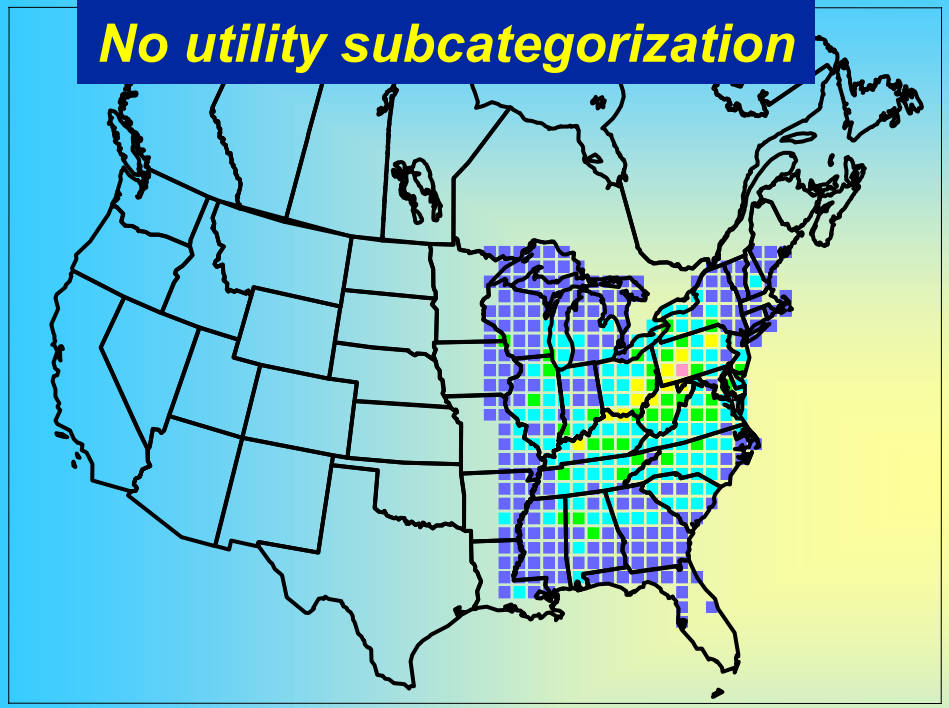
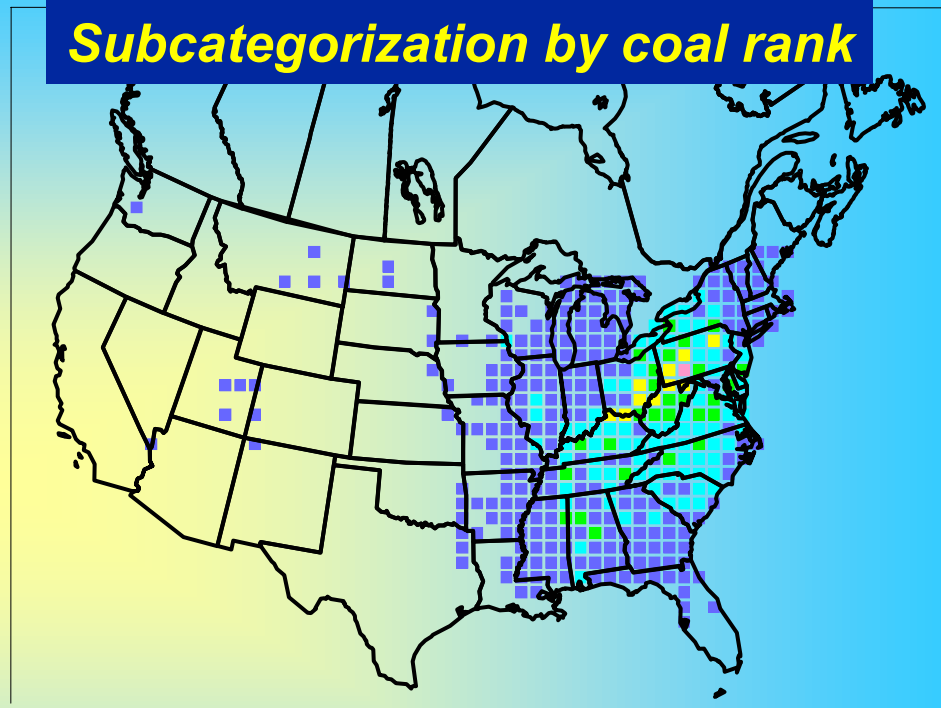
Deposition patterns under the 2 scenarios (both coarse grid)

Scenario 1:
No utility subcategorization



Scenario 2:
Subcategorization by coal rank



1 to 5%
5 to 10%
10 to 20%
20 to 30%
30 to 33%

Percent difference in annual mercury deposition from base case

(= current emissions) and given scenario (scenario deposition is always less than base case deposition)

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Some remaining issues

- We need a mass balance:
  - many uncertainties in global balance of mercury, esp. natural sources;
- How quickly will mercury deposition drop? Mercury in fish? Mercury in humans?
  - even industrial sources unclear (Peterson source near Moscow)
- What is the most efficient strategy for managing mercury risk?
- Is there a management “floor”? Does so much U.S. mercury originate outside the U.S. that U.S. controls make little difference in many areas?